CENTER FOR GLOBAL DEVELOPMENT

A CALL TO ACTION TO END CHILDHOOD LEAD POISONING WORLDWIDE

Final Statement of the Working Group on Understanding and Mitigating the Global Burden of Lead Poisoning

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A NEGLECTED, TOP-TIER DEVELOPMENT CHALLENGE

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Text by Rachel Silverman Bonnifield and Rory Todd

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Executive Summary

This document represents the final statement of the Working Group on Understanding and Mitigating the Global Burden of Lead Poisoning.* The Working Group concludes that lead poisoning represents a profound and preventable threat to health, education, and development prospects around the world, with the burden concentrated in low- and middle-income countries (LMICs). The scale of harm from lead is staggering: an estimated 815 million children (one in three worldwide) have exposure levels that can be considered lead poisoning; lead is estimated to drive a fifth of the global learning gap between high-income countries and LMICs; and lifelong lead exposure is estimated to cause between 1.6 and 5.5 million deaths each year from cardiovascular disease.

Despite the extraordinary health, learning, and economic toll attributable to lead, we find the global lead poisoning crisis remains almost entirely absent from the global health, education, and development agendas. Many LMIC leaders are unaware of how widespread lead poisoning is in their own countries, most countries have no systems in place to detect and prevent lead exposure, and relative to its burden, very limited international funding is available for preventing and mitigating lead poisoning in LMICs. Nevertheless, evidence suggests that significant progress is possible within a short time frame given sufficient political will and modestly increased finance. We estimate that US$350 million in development assistance through 2030—just $50 million a year—would be sufficient to transform the landscape and mobilize scaled action to address lead poisoning in LMICs. We call on global leaders to take bold and urgent action to end childhood lead poisoning by 2040[1] —no matter where those children live.

* This document represents the final statement of the Working Group, resulting from the past year of its deliberations. The statement does not necessarily represent the views of all Working Group participants (or the groups with which they are affiliated); nor does it represent a policy commitment from any individual or institution. Some members of the Working Group (listed below) have opted to sign the statement in their individual capacities. Non-signatory members of the Working Group have provided input that informed the final statement, but they do not necessarily endorse its contents.

Final Statement

LEAD EXPOSURE HURTS HUMAN HEALTH AND WELFARE

- Lead is a widely used and highly toxic metal, with neurological effects that are especially hazardous to children.
- Lead's effects on the human body are extensive and profound, impacting almost every bodily system. There is no safe level of lead;[2] neuro-cognitive effects in children[3] and cardiovascular health effects in adults are apparent even at very low levels of exposure.[4]
- A shared understanding of lead's danger has already motivated dramatic global action to reduce the burden of lead exposure—specifically, the complete global phase-out of leaded petrol.[5]
- Lead poisoning is preventable; most cases of lead exposure result from sources with safe and readily available alternatives. Eliminating ongoing lead exposure is needed to prevent brain damage in children and the loss of potential of entire generations.
- Nevertheless, lead remains a valuable and in-demand commercial commodity.[6] Some industrial applications of lead are still considered "essential"[7] by some stakeholders—most notably use within lead-acid batteries, which account for more than 85 percent of lead in current circulation.[8]
- Most wealthy countries have dramatically reduced lead exposure since they took domestic actions to do so, including the phase out of leaded petrol and lead paint, though hot spots of lead exposure remain in some locations, particularly among vulnerable populations.[9]

LEAD POISONING REMAINS WIDESPREAD ACROSS LOW- AND MIDDLE-INCOME COUNTRIES

- The danger of lead is well recognized, but the scale of ongoing global lead exposure is not.
- Though data is limited, current estimates suggest that **the scale of lead poisoning[10] today remains extraordinary**, impacting an estimated 815 million children—one in three children worldwide.[11]
- **Most of these children live in LMICs**; in low-income countries, it is estimated that more than half of children have lead exposure levels that can be considered lead poisoning,[12] along with high proportions of adults.[13]
- Within LMICs, significant sources of lead remain and continue to be introduced into the natural and home environments.[14]
- The sources of ongoing lead exposure vary within and across LMICs, but include battery recycling, spice adulteration, ceramic and aluminum cookware, cosmetics, paint, environmental contamination, and traditional medicines, among others. The relative contribution of these different sources is not yet well characterized.[15]

ONGOING LEAD EXPOSURE IS A PROFOUND, PREVENTABLE, AND NEGLECTED THREAT TO HEALTH, EDUCATIONAL, AND DEVELOPMENT PROSPECTS IN COUNTRIES AROUND THE WORLD

- Through its impact on children's cognitive development, lead exposure is estimated to be responsible for over a fifth of the learning gap between high-income countries and LMICs.[16] Through this mechanism, a new analysis by the World Bank estimates that lead exposure drives a loss of income worth US$1.4 trillion, equivalent to 1.6 percent of global GDP.[17]

- Lead exposure is recognized as a causal risk factor for cardiovascular disease by the American Heart Association.[18] Through this mechanism, estimates suggest that chronic lead exposure is responsible for between 1.6 and 5.5 million deaths globally each year.[19] Even at the low end of this range—e.g., the current figure put forth by Institute for Health Metrics and Evaluation (IHME)—the death toll from lead exposure far exceeds deaths from either HIV/AIDS or malaria.[20] A recent World Bank estimate attributes 5.5 million deaths per year to lead exposure, roughly rivalling the death toll from particulate air pollution. The World Bank calculates the cost of this burden to be equivalent to $4.6 trillion, or 5.3 percent of global GDP.[21]

- Childhood lead exposure has a likely though not conclusive role in increasing the prevalence of subsequent conduct disorders, with some evidence also suggesting a link with aggression and criminal behavior.[22] We note that a causal link between lead exposure and these outcomes, if robustly established, could have major implications for many different global challenges, including intimate partner and domestic violence; crime and policing; and gang violence.

- Lead exposure is also a significant contributor to kidney disease,[23] and ongoing scientific inquiries are exploring hypotheses that even low lead exposure may further contribute to amyotrophic lateral sclerosis,[24] Alzheimer's disease,[25] and antimicrobial resistance,[26] though such links are still unproven.

- Though not the focus of this Working Group, lead exposure is also a serious threat to the environment, ecosystems, and biodiversity, particularly among birds, mammals, and reptiles.[27]

- Eliminating sources of future exposure, even among those previously exposed, has significant benefits at the individual and population levels.[28]

- Relative to its scale and impact, lead poisoning is extraordinarily neglected; many LMIC leaders are unaware of how widespread lead poisoning is in their own countries, most have no systems in place to detect and prevent lead exposure, and we were able to identify just $11 million in annual philanthropic funding for preventing and mitigating lead exposure in LMICs.[29]

LEAD POISONING SHOULD BE ELEVATED AS A TOP-TIER GLOBAL DEVELOPMENT CHALLENGE

- Lead exposure is a top-tier impediment to global health, education, and economic development; it robs children of their ability to learn and thrive, and deprives adults of years of healthy life.

- Lead exposure is a significant barrier to achieving almost all of the Sustainable Development Goals; it threatens efforts to make progress on poverty, inequality, early childhood development, health, education, growth, clean energy, sustainability, responsible consumption, and the health of oceanic and land-based ecosystems.[30] It also endangers countries' potential to benefit from the demographic dividend.[31]

- Addressing the global crisis of lead poisoning deserves urgent prioritization as such from national governments, development partners, philanthropists, and multilateral organizations. It should be considered a priority not just for public health and the environment, but also for the education sector and overall child welfare.

- The scale of the crisis demands a multipronged, multiscale approach—one that integrates international, national, and local actions, and which pairs short-term interventions with development of long-term national regulatory, enforcement, and surveillance capabilities in LMICs.
- While the elimination of lead poisoning is a long-term project, there are important tractable steps that can be taken in the short term. There are notable recent success stories from LMICs in removing lead-contaminated products from the market, and there are affordable, highly cost-effective, and immediately actionable measures to do so.[32] There is some evidence such interventions have resulted in significant decreases in population blood lead levels.[33] In the short-term, broad-based public health and regulatory measures (including regulations and enforcement) to eliminate lead in spices, paint, and consumer goods, and to reduce lead exposure from battery recycling, have the highest potential to cost-effectively reduce lead exposure at scale.[34]
- LMIC governments are in the driver's seat to address this issue—but development partners and philanthropists have an essential catalytic and ongoing role to play in mobilizing advocacy and high-level attention, building capacity for regulation and enforcement, and providing proof of concept for interventions to reduce lead exposure. In particular, generation of local evidence on the prevalence, severity, sources, and/or impact of lead exposure can be very helpful in motivating national action.[35]
- We estimate that $350 million in development assistance through 2030—just $50 million per year—would be sufficient to mobilize scaled action in LMICs.[36] A small and sustained percentage of total global philanthropic giving or official development assistance would be transformative.
- Effective advocacy, stakeholder engagement, and grassroots mobilization are essential to raise awareness of lead poisoning at the international, national, and local levels; to increase the urgency and accountability of action by governments, international bodies, and industry to reduce lead exposures and contamination, including via effective legislation, regulation, and enforcement; and to empower families and communities to protect themselves from lead exposure to the extent possible. Advocacy should be broad-based and multisectoral, helping motivate public health, medical, environment, education, and industrial constituencies to take action.
- Opportunities for effective intervention remain constrained by serious data and evidence deficits. There is an urgent need for further research and data collection, including vis-à-vis the local and global prevalence, severity, and impact of lead poisoning; the relative contribution of different sources of lead exposure at the global, regional, and local levels; and the effectiveness and cost-effectiveness of interventions to reduce lead exposure and blood lead levels.
- There is also a need for research and development for further solutions, including improved and lower-cost technologies for exposure detection, source evaluation, and remediation. More research is needed to evaluate and compare the efficacy and cost-effectiveness of environmental, policy, and medical interventions.

THE WORKING GROUP CALLS FOR DRAMATIC ACTION

- We call on global leaders to take bold and urgent action that will end this slow-moving crisis; protect children's potential to learn and thrive; and dramatically reduce unnecessary, preventable deaths from cardiovascular disease.

- As a global community, we must **pledge to end lead poisoning for the next generation of children**—no matter where they live.
  - Every country should begin working today to end childhood lead poisoning by 2040; in concrete terms, this means ensuring that to the extent possible every child has a blood lead level below 5 µg/dl, and progressively reducing levels "closer to zero"[37] below that point.
- Since children in LMICs are disproportionately affected, LMIC governments must work urgently with support from development agencies, the UN system, and multilateral development banks to take national action to **reduce and prevent additional lead contamination** of homes, workplaces, supply chains, and the environment, including through strict regulations (and their enforcement) on all sources of lead, extended producer responsibility where it is required, and bans on non-essential uses in consumer products.
- To support immediate mitigation efforts, as well as longer-term progressive reductions in blood lead levels, countries should urgently build surveillance systems for nationally representative blood lead measurement combined with source assessment where necessary, calling on the assistance of WHO and UNICEF as needed and appropriate, with a goal of reporting initial results by end-2026. Development agencies, multilateral development banks, and international organizations should provide financial and technical support for these efforts, also as needed and appropriate, including to help build laboratory and field sampling capacity.
- In parallel, countries should work to evaluate and integrate lead exposure prevention and lead poisoning diagnosis and treatment into universal health coverage systems, as appropriate for their respective levels of development and resource availability. This should include adaptation and implementation of WHO guidelines on managing lead exposure, and ensuring the availability of diagnosis and indicated treatment (chelation therapy) for severe lead poisoning.[38]

About this Statement

In 2022, the Center for Global Development convened a multistakeholder Working Group on Understanding and Mitigating the Global Burden of Lead Poisoning. Its members include policymakers from affected countries; senior figures in multilateral development banks, philanthropies, NGOs, and international organizations; and subject matter experts in lead poisoning, health, education, and economic development. Members served in their individual capacities.

The group met three times and maintained correspondence over the course of 16 months. The Working Group was tasked with the following mandate and objectives:

- Define evidence needs and a research agenda to better understand the global burden of lead poisoning.
- Deliberate over evidence of the global burden of lead poisoning and potential mitigation strategies.
- Issue a final statement, including actionable recommendations to a well-defined set of stakeholders to better understand and mitigate the global burden of lead poisoning.
- Increase awareness, salience, and prioritization of lead poisoning at the global and local levels, proportionate to its importance as a global health, education, environmental, and development issue.

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All errors and omissions are attributable to the authors alone.[**]

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Endnotes

1 In concrete terms, this means ensuring that to the extent possible every child has a blood lead level below five micrograms of lead per deciliter of blood (μg/dl), and progressively reducing levels "closer to zero" (toward pre-industrial levels) below that point. This choice of threshold is explained in endnote 10.

2 There is a wealth of studies on the effects of subclinical lead exposure, particularly with respect to cognitive development in children. As is common for environmental exposures like pollutants or tobacco—and necessarily for ethical and technical reasons—these studies are associational rather than experimental. There are several reasons, nevertheless, to interpret the relationship as causal. Firstly, the consistency of a moderately strong effect across many, well-controlled studies conducted in a range of contexts; secondly, several natural experiments finding causal effects using a range of methods; thirdly, animal model studies documenting effects in experimental conditions; and finally, several plausible mechanisms for how lead might affect brain development. A more detailed assessment of this evidence can be found in Crawfurd et al. (2023).

Several studies have attempted to identify a threshold below which lead exposure is non-toxic (e.g. Schwartz et al. 1994) but associations with cognitive deficits have been identified even at levels previously considered very low (Huang et al. 2012, Aizer et al. 2018). In fact, effects seem to be stronger at lower levels; i.e. the same increase in blood lead has a stronger detrimental effect on cognitive development at a lower baseline (Lanphear et al. 2005).

3 A recent paper (Crawfurd et al. 2023) estimates that a natural log unit increase in blood lead results in a −0.12 standard deviation decrease in learning outcomes. Based on estimates of blood lead levels in LMICs made by Ericson et al., this effect implies that differences in lead exposure could explain around 21 percent of the gap in educational achievement between rich and poor countries.

4 Lamas et al. (2023).

5 Concerns around the health impacts of adding tetraethyl lead to petrol as an anti-knocking agent date back to its introduction in the United States in the early 1920s—spurred not least by numerous cases of acute lead poisoning in petrol handlers and workers in processing plants—but industrial lobbying forestalled governmental regulation until the 1970s (Nriagu, 1990). Even then, and despite readily available alternatives, its phase-out was a gradual—and contentious—process across developed countries. Most LMICs only introduced regulations in the early 2000s, driven in part by the Partnership for Clean Fuels and Vehicles, an initiative under the United Nations Environment Programme (UNEP). It wasn't until 2021 when Algeria stopped offering leaded fuel to drivers that the world became completely free of leaded petrol for road vehicles (see https://news.un.org/en/story/2021/08/1098792). Aviation petrol (avgas), used in light piston-driven aircraft, still commonly contains tetraethyl lead. In 2008 the EPA [p. 23] found that more than half of the flow of atmospheric lead was attributable to Avgas, and there is increasing evidence from the United States of raised blood lead levels near airports where avgas is used (e.g., Zahran et al., 2017).

6 Growing demand for lead-acid batteries, which are primarily used in vehicles but also as back-up power supplies and for green energy storage, has resulted in the price of lead roughly quadrupling from a low point in the early 2000s (Trading Economics, 2023). This has in turn stimulated a rapid expansion in lead mining (Rees and Fuller, 2020, 47), as well as the recycling of lead from used batteries.

7 We refer to current language in use by the European Commission on the subject, which states that "the most harmful chemicals are only allowed if their use is necessary for health or safety reasons, or if their use is critical for the functioning of society and if there are no acceptable alternatives from the environmental and health viewpoints" (European Commission, 2020). Currently, use within lead-acid batteries is considered the most notable and important "essential" use of lead; however, we note that technological innovation, paired with targeted incentives, could lead to the obsolescence of the lead-acid battery over the medium- to long-term in favor of, e.g., lithium-ion batteries. There are likely to be other niche industrial use cases that meet these high-level criteria for "essential" use. Uses of lead are considered "non-essential" when there are technically and economically viable substitutes, or when the use case itself is of marginal or negative social and/or economic value. Non-essential uses of lead are numerous, and include use within pigments, paints, and glazes; weights and tackles; cosmetics; alterative medicines and supplements; jewelry; and so forth. There is some middle ground between these two categories where the "essential" nature of lead is contested. One notable example, here, is use of lead within ammunition and artillery, for both military and non-military use; though there are now substitutes (e.g. copper ammunition), they may not be cost-competitive, entirely equivalent in performance, or compatible with all weaponry.

8 Rees and Fuller, 2020: 2.

9 Children's blood lead levels (BLLs) in the United States have declined steadily since the late 1970s, with median levels decreasing from 15 micrograms of lead per deciliter of blood (µg/dl) in the late 1970s, to 3.5 µg/dl in the late 1980s, and to 0.6 µg/dl by 2018 (Egan et al., 2021). Few other high-income countries have such complete biomonitoring data, but a systematic review (Hwang, 2019) found that they tended to follow a similar trend. Children in the US more likely to have higher BLLs include those from low-income households, African Americans, and immigrants and refugees (Centers for Disease Control and Prevention (CDC) n.d.). Higher levels among low-income households can be partly attributed to their propensity to live in houses built before 1978, when the use of lead in household paints was banned (CDC n.d.). The evidence on the location of hotspots, as well as methods to identify them, have been summarized in a recent state-of-the-science review by researchers from several US government agencies (Zartarian et al., 2022).

10 We are not aware of a consensus definition for levels or symptoms of lead exposure that constitute "lead poisoning." For the purposes of this statement, we define *lead poisoning* as blood lead levels (BLLs) exceeding 5 micrograms per deciliter (µg/dL). (We note that our use of this term differs from some medical usage, which may refer to *lead poisoning* only at levels above 20 µg/dL and/or where visible symptoms are apparent.) The 5 µg/dL is not a biological threshold of great significance, but represents a standard formerly used by the US Centers for Disease Control to indicate higher lead exposure than most US children; it is still used by the World Health Organization (WHO) and commonly applied as a benchmark reference level. We note that since there is no safe level of lead, the negative impacts of lead exposure occur even at BLLs below 5 µg/dL. We therefore use the term lead exposure as an umbrella term that encompasses both *lead poisoning* and exposures resulting in BLLs below 5 µg/dL. We use the term *acute lead poisoning* to refer to the subset of *lead poisoning* cases that result in visible symptoms, typically at BLLs above 30 µg/dL. We use the term *severe lead poisoning* to refer to the subset of *acute lead poisoning* cases that result in serious neurological or other symptoms, and which are likely eligible for chelation therapy, typically at BLLs above 45 µg/dL. (We note that the WHO guidance refers to "severe" lead poisoning as typically occurring above 70 µg/dL.)

11 Existing data on the prevalence of lead poisoning is extremely limited, with only two LMICs (Georgia and Mexico) having recent nationally representative surveys of children's blood lead levels (BLLs), and many countries having no reliable data whatsoever. Two groups have attempted to make estimates for a large set of LMICs based on limited existing data.

The Institute for Health Metrics and Evaluation (IHME) produce estimates for all countries—mostly via imputation—for the Global Burden of Disease study; these results were also used in the *Toxic Truth* report (Rees and Fuller, 2020, 21). They estimate that 815 million of children and adolescents up to the age of nineteen—approximately a third globally—have BLLs exceeding 5 μg/dL. In 2021, Ericson and colleagues crafted a complementary set of estimates for a group of 34 LMICs, based on a more comprehensive set of data sources; their results differed quite strongly country-to-country with those made by IHME, and were on average somewhat higher. Overall, even allowing for the substantial uncertainty in assessing global prevalence, we have a very high degree of confidence that levels in LMICs are high enough to constitute a major burden to public health.

12 CGD analysis of IHME estimates (Rees and Fuller, 2020, 67).

13 IHME do not estimate exposure levels for adults, but Ericson and colleagues do so for 37 countries. For countries with estimates for both children and adults, they generally find somewhat higher levels among children (although for some countries the opposite was found). The discrepancy may be due to children's higher rate of absorption of ingested lead (WHO, 2021, 11). Levels for adults were nonetheless dangerously high, with an unweighted average mean of 3.83 μg/dl.

14 See discussion in Silverman Bonnifield and Todd (2023, 13).

15 See discussion in Silverman Bonnifield and Todd (2023, 18).

16 In this working paper (Crawfurd et al. 2023), the authors conducted a meta-analysis of studies measuring the effect of lead exposure on either IQ or math and reading test scores. Their result, which attempted to account for potential confounding as well as publication bias in the literature, was then applied to estimated blood lead levels (BLLs) in LMICs (Ericson et al., 2021), to simulate the average effect on test scores of reducing BLLs to median levels in the United States (Egan et al., 2021).

17 Larsen and Sanchez-Triana, 2023. The authors used an estimate from Crump et al. for the effect of lead on IQ, and an IHME estimate for global blood lead levels. They find that in 2019, 765 million IQ points were lost in children under five due to lead exposure. They then use an income effect of 2 percent per IQ point to calculate a total burden of $ 1.4 trillion lost due to the effect of lead exposure on cognitive development. Another study (Attina and Trasande, 2013) estimated the economic burden of cognitive losses accrued from lead exposure to be equivalent to 1.2 percent of global GDP.

18 A statement by the American Heart Association in June 2023 concluded that "the totality of evidence supports the notion that environmental metal exposure [including from lead] increases the risk of premature cardiovascular death by contributing to CVD progression, severity, and clinical outcomes." Lead is a risk factor particularly for ischemic heart disease, but also stroke and peripheral arterial disease.

19 The disparity in estimates is due principally to key methodological differences in how the effect of lead exposure on the risk of cardiovascular disease (CVD) is estimated. IHME's estimate of around 1.6 million deaths per year only accounts for the estimated effect of lead exposure on systolic blood pressure, which it draws from a 2008 meta-analysis by Navas-Acien and colleagues. This approach is conservative, as lead exposure has detrimental effects on the cardiovascular system additional to those mediated through blood pressure. Another approach, used for the World Bank's estimate of 5.5 million deaths, is to estimate the effect of lead exposure on cardiovascular mortality directly. Four studies have estimated this, all based on the National Health and Nutrition Examination Surveys. Estimates still differ significantly, with resultant estimates of global deaths therefore ranging from 2.3 to 8.3 million (Larsen and Sanchez-Triana, 2023). The World Bank authors average the two central estimates; they chose this approach because the underlying data on which these estimates are based is most similar to levels observed in LMICs. This results in a preferred estimate of 5.5 million deaths per year.

There are significant remaining questions about the exact nature of the relationship between lead exposure and CVD risk. Perhaps most importantly, we do not know the extent to which a *short-term* reduction in lead exposure would reduce CVD risk for populations with lifelong, cumulative exposure; therefore, we do not know whether immediate reductions in *current* blood lead levels (BLLs) would meaningfully reduce CVD deaths in the short term. (Over the long term, benefits would accrue to future generations, who would receive less lead exposure in childhood/early adulthood, and then see reduced cardiovascular risk at older ages.) There is some emerging evidence that short-term changes in BLL can affect risk of hypertension; see slide 14 here, for example (manuscript under review), but the evidence base is still immature.

20 IHME estimates annual deaths resulting from HIV to be 863,000 (IHME n.d -a)., and deaths resulting from malaria to be 643,000 (IHME n.d. -b). However, on average, cardiovascular deaths occur among older age groups than HIV and malaria; consequently, estimates for Years of Life Lost and Disability-Adjusted Life Years are higher for HIV and malaria than for lead exposure.

21 Larsen and Sanchez-Triana, 2023.

22 Antisocial and aggressive behavior is an established symptom of moderate or severe cases of lead poisoning, but in recent years studies have found links to even very low exposures. A meta-analysis by Marcus and colleagues (2010) found an association between lead and conduct problems in children and adolescents, with a similar magnitude to the effect of lead on IQ. The link to criminal behavior is more disputed. Two recent systematic reviews summarize the evidence on the issue. Higney and colleagues (2022), conducting a meta-analysis of a broad range of studies, find a substantial effect even after adjusting for detected publication bias; their estimates imply that declines in lead exposure explain 7–28 percent of the fall in homicide in the United States since the late 1970s. Talayero et al. (2023), restricting their synthesis to studies using individual-level data, find smaller, but still substantial effects. The US National Toxicology Program concluded that there was "sufficient evidence that blood Pb levels <5 µg/dL are associated with antisocial behavioral problems or actual criminal behavior in children from six to 15 years of age" (NTP 2012, 34).

23 Chronic exposure to lead can lead to chronic renal failure (WHO 2021, 36), which by increasing blood pressure can also exacerbate the effects of lead on the cardiovascular system.

24 The US National Toxicology Program concluded that there is "limited" evidence for an association between blood lead levels below 10 µg/dl and a higher risk of Amyotrophic Lateral Sclerosis (ALS). A number of case-control studies have reported significant associations between lead exposure and ALS, and this is supported by several animal model studies (National Toxicology Program (NTP) 2012, 38). Several of the human studies have potential issues with reverse causality, although Fang and colleagues (2010) attempted to address this and still found an association.

25 Animal model studies have found lead to cause many of the characteristic markers of Alzheimer's disease (Islam et al., 2022), although there is currently inadequate evidence on low levels of exposure from human studies (NTP 2012, 39).

26 The US National Toxicology Program concluded that there was limited evidence that moderate lead exposure (<10 µg/dl) in children was associated with adverse immune effects (NTP 2012, 45). A study from 2021 found that lead exposure was associated with increased colonization by antibiotic-resistant bacteria, particularly fluoroquinolone-resistant Gram-negative bacilli (RGNB) (Eggers et al., 2021).

27 Lead exposure is a critical One Health issue, defined by the WHO as "an integrated, unifying approach to balance and optimize the health of people, animals and the environment" (WHO, 2017). Environmental lead contamination can harm wildlife populations and in turn threaten humans via contaminated food supply.

28 The United States Air Quality Criteria for Lead report concluded that the balance of evidence supports neurotoxic effects of lead being at least partly irreversible (US EPA 2013: 1-60). This is based on toxicological as well as animal studies. There are also several plausible mechanisms for lead exposure leading to permanent loss of brain development. However, some studies have found evidence that at least some of the effect is transient—i.e. effects fade away once an individual's exposure decreases (US EPA. 2013:1-60). The evidence on cardiovascular disease is less mature, and the relative contributions of long-term chronic exposure versus short-term recent exposure has not been fully clarified.

29 Below is a rough estimate of annual philanthropic funding for lead exposure mitigation in LMICs. The estimate was compiled based on a desk review and conversations with almost all relevant funders and organizations working in this space. All currently funded projects were eligible. For each organization, we used funding for the most recent year for which data was available (e.g., if we only had data on funding for an organization up to 2021, we used the figure for 2021). There are two relevant caveats. First, we cannot guarantee its comprehensiveness, although given the scope of our inquiry, CGD believes it is unlikely that we overlooked any major organizations (e.g., >$1 million per year). Second, we needed to make assumptions in several cases about the proportion of a broader project/annual organizational funding that was relevant; e.g., if a grant addressed lead in addition to other chemicals, or if a grant addressed both domestic (high-income) and global (LMIC) lead exposure.

CGD's estimate of annual philanthropic funding, broken down by implementing organization, is as follows. You may email the authors for further details on how these figures were sourced and calculated.

ORGANIZATION	ESTIMATED ANNUAL PHILANTHROPIC FUNDING, GLOBAL LEAD (US$ M)
Pure Earth	5,991
Lead Exposure Elimination Project (LEEP)	1,260
UNICEF	1,250
Vital Strategies	750
Stanford University	691
Center for Global Development	600
International Pollutants Elimination Network (IPEN)	500
Occupational Knowledge International	95
Total	**11,137**

This figure does not account for actions by national governments within LMICs themselves, as well as several projects funded by bilateral donors and foreign governments or multilateral development banks. We are aware of several of these projects:

- The World Bank has funded a project to remediate polluted mining areas in several municipalities in Zambia. This includes Kabwe, which has been severely contaminated by lead mining. The project as a whole was funded through an original loan commitment of $ 65.6 million, of which $ 32.2 million was disbursed from January 2018 to August 2023.
- Another World Bank project in the Lao People's Democratic Republic, the Second Programmatic Green Growth Development Policy Operation, included—as one of 14 priority actions—an objective that the government would introduce new standards and monitoring requirements for environmental pollutants, including lead.

- USAID runs a lead mitigation program, with $ 1.5 million of annual funding.
- The United Kingdom Health Security Agency provides official development assistance-funded technical support to assist governments in LMICs with complying to International Health Regulations. This includes building technical capacity for the management of chemicals, including of lead.
- Other forms of in-kind and technical assistance support (e.g., government to government cooperation) for mitigating lead poisoning in LMICs also exist.

30 The Sustainable Development Goals (SDGs), adopted in 2015, represent an ambitious, wide-ranging agenda for human thriving and environmental sustainability (United Nations Department of Economic and Social Affairs n.d.). Lead poisoning/exposure is not directly referenced in the goals or constituent targets, though lead exposure should be included under 3.9 ("By 2030, substantially reduce the number of deaths and illnesses from hazardous chemicals and air, water and soil pollution and contamination.") More broadly, lead exposure is a meaningful factor detracting from efforts to achieve almost all SDGs. Most obviously and directly, lead exposure detracts from SDG 3: healthy lives and well-being at all ages. Through its effects on children's cognition and learning—and consequent economic impacts—lead exposure also compromises efforts to end poverty (SDG 1), ensure quality education (SDG 4), and promote decent work and economic growth (SDG 8). Use of lead pipes, as well as lead contamination of water tables, threatens the goal of clean water and sanitation (SDG 6). Lead is additionally implicated in the sustainable energy and climate agenda. Pollution from lead-acid battery recycling is a major challenge for sustainable urban living (SDG 11), while solving the problem of lead-acid battery recycling is a core issue for responsible consumption and production (SDG 12). Doing so is also essential for electrification and renewable energy goals (SDG 7), which in turn contributes to climate action (SDG 13). Finally, the effects of lead exposure on wildlife detract from marine conservation (SDG 14) and protection of terrestrial ecosystems (SDG 15).

31 The "Demographic Dividend" refers to a period in countries' overall development when fertility rates rapidly drop (UNPF n.d.). In this moment of transition between high- and low-fertility rates, countries see a "bulge" of working-age adults, with a relatively low dependency ratio; this generation's productivity can kick-start savings, economic output, and investment in future generations, thereby beginning a virtuous cycle of human and economic development. Lead exposure does not alter this fundamental demographic dynamic but can compromise countries' ability to realize the purported benefits. The primary mechanisms for this are twofold. First, lead exposure substantially impedes educational outcomes; this means that the working-age population will likely be less educated and productive than they would be in a counterfactual in which they were not exposed to lead in childhood. Likewise, their children's learning will be similarly hampered—with the effects of lead exposure to some extent counteracting positive investments in education—and the intergenerational benefits will slow. Second, through lead's effects on cardiovascular disease, the working age population is likely to develop premature cardiovascular morbidity and mortality, which will reduce their productivity and/or ability in the workforce, in turn increasing the dependency ratio.

32 The clearest recent examples of the success of regulatory action in reducing lead in products in LMICs relate to lead paint. A project coordinated by the International Pollutants Elimination Network (IPEN), which supported the introduction of standards on lead paint in seven Asian countries, resulted in the market-leading brands in all countries eliminating lead from decorative paints (International Pollutants Elimination Network (IPEN) 2015). A before-after study by Clark and colleagues (2014) found the same pattern after regulations were introduced in India and Brazil.

More recently, there have been notable successes in efforts to end the adulteration of spices with lead chromate. In Georgia, after a study conducted by Pure Earth identified high levels of contamination within select spices as a key driver of elevated blood lead levels in children, the government introduced regulations to end the practice. The director for Pure Earth Georgia reported that two years after this intervention, lead had been eliminated from spices in Georgia (Pure Earth, 2022). In Bangladesh, the discovery of high levels of contamination of turmeric by lead chromate led to an aggressive public awareness campaign and the introduction of fines for offending wholesalers. After this intervention, the rate of highly contaminated spice samples dropped from 50 percent to 5 percent (Pure Earth, 2021). Data from New York City found that lead levels in spice samples from both Georgia and Bangladesh decreased substantially after the introduction of regulations in each country (Paromita Hore, personal communication).

33 After the intervention in Georgia described above, a survey found that median levels in their sample had decreased from 9.6 µg/dL in 2018 to 7.1 µg/dL in August 2019, and to 6.8 µg/dL in late 2019, although the latter decrease was not statistically significant (Ruadze, 2021). Preliminary results from Bangladesh (Jenna Forsyth, personal communication) show that a national sample of women and children in 2023, after the intervention against the adulteration of turmeric, had blood lead levels 20–30 percent (1-2 µg/dL) lower than a matched sample from 2011–2013.

34 This list is derived from the Working Group's deliberations and its collective expertise and experience. We give our justification for these immediate focus areas below. Although we do not specifically discuss general regulations on consumer goods, they should follow similar logic to spices and paint in the regulatory framework and potential enforcement actions:

- **Spices**: The Working Group reached general agreement that one of the highest-impact immediate steps to prevent ongoing lead exposure is to end lead contamination of spices. While the exact contribution of spice contamination to overall lead exposure is unknown, there are several indicative data points that suggest it may be quite high, at least in some countries—which is logical, given that it represents direct contamination of food products that are widely and frequently consumed by very large swathes of the population. In rural Bangladesh, a study (Forsyth 2019) using isotopic analysis found strong evidence that adulterated turmeric was the leading cause of high blood lead levels (BLLs) among pregnant women. Pure Earth came to a similar conclusion after a source apportionment study in Georgia. As contaminated spices have been identified in many other countries stretching across North Africa, the Middle East, and Central and South Asia, we have reason to believe the problem is widespread in some regions, even if we cannot confirm the relative importance in each country or region.

  In addition, we now have multiple data points suggesting that removing lead from spices is highly *tractable* at relatively low cost. Interventions to do so are aided by relatively easy detection, which can be done quickly and easily using field-based x-ray fluorescence devices within processing facilities, warehouses, and marketplaces—creating an opportunity for instant, low-cost, spot enforcement. Given the global reach of supply chains and the relative concentration of processing facilities, enforcement interventions can be extraordinarily cost-effective. In Georgia, a Pure Earth pilot project identified spices as a major source of childhood lead exposure; in partnership with the Georgian government, this source of contamination was drastically curtailed over a two-year time span via new regulation and enforcement; producer awareness along the entire supply chain; and consumer education (Pure Earth, 2021). Long-term monitoring will confirm whether this reduction persists. Actions taken abroad likely also contributed towards the decline in the number of children with elevated BLLs among New York City children with Georgian ancestry (Paromita Hore, personal communication). In Bangladesh, a baseline market analysis in 2019 found that 50 percent of turmeric samples were lead-contaminated, and 31 percent of polishing facilities showed signs of lead adulteration (Forsyth, 2023). A subsequent intervention involved: 1) fining lead wholesalers and confiscating contaminated merchandise; 2) more broadly screening turmeric samples for lead, and warning sellers about the possibility of fines; and 3) a broad public awareness and education campaign. Measurements in 2021 found no samples containing lead, and no evidence of spice adulteration with lead chromate at any polishing plant.

- **Paint**: An additional high impact, immediate intervention to reduce lead exposure is eliminating lead paint. Despite readily available alternatives, there are still 71 countries without legal controls on lead paint (WHO n.d.), and paints with high lead levels have been found in all countries where this is the case (IPEN, 2020). As with all sources of exposure, there is uncertainty on the contribution of lead paint to lead poisoning globally; one recent analysis estimated that lead paint accounts for 7.5 percent of the economic burden of lead, while acknowledging high uncertainty (Kudymowa et al., 2023). Others view it as a potentially highly important source of exposure. It is also a source for which there are established interventions. A recent project funded by the Global Environment Facility, promoting the introduction of controls on lead paint and assisting with implementation including by provision of a model law for lead paint regulation, is claimed to have resulted in 21 countries enacting legislation to do so (UNEP, 2023). Recent interventions by IPEN and LEEP have demonstrated that it is possible to quickly and effectively remove lead paint from the market via engagement with manufacturers, coupled with new regulations and/or enforcement campaigns by government (LEEP, 2023). Removing lead from paint is an investment that yields benefits over a very long time horizon, as any new paint becomes a *de facto* permanent feature of housing/building stock and/or environmental contamination in the case of demolition. (While safe lead paint remediation is technically possible, it is very costly and challenging to do at scale; in most LMICs, it is a safe assumption that the vast majority of lead paint will never be remediated through such techniques.) The benefits, though spread out over a longer time horizon, are easily large enough to justify the modest up-front costs. The aforementioned analysis also estimates "that doubling the speed of the introduction of lead paint bans across LMICs could prevent 31 to 101 million (90% CI) children from exposure to lead paint, and lead to total averted income losses of USD 68 to 585 billion (90% CI) and 150,000 to 5.9 million (90% CI) DALYs over the next 100 years."

- **Battery recycling**: Lead-acid batteries account for most lead used in the world and are essential for both traditional and electrified transport. While it is therefore not possible to eliminate this use at least in the short term, robust regulatory solutions, where in place and enforced, can virtually eliminate lead exposure from battery recycling among plant workers and the surrounding communities. This is in contrast to the status quo in many LMICs, where battery recycling is often carried out in sub-standard formal facilities or via informal (backyard) smelting operations, and where severe environmental contamination and acute lead poisoning are common among local families (Rees and Fuller, 2020, 28). A full discussion on the challenges of battery recycling can be found in Silverman-Bonnifield and Todd (2023, 19). Battery recycling is an established driver of acute lead poisoning, although its contribution to overall population exposure is less certain. One analysis estimates that six to 17 million people are exposed by informal battery recycling sites globally—compared to 815 million children thought to have lead poisoning—although for those affected, exposure levels are estimated to be very high, with exposed children having an average BLL of 31 µg/dL (Ericson et al., 2016). Regulatory intervention is therefore needed to ensure battery recycling occurs only in safe, highly regulated environments.

There is a good understanding of what facilities and supply chains are required for the safe recycling of lead-acid batteries, and the Secretariat of the Basel Convention has provided technical guidelines on this process (Secretariat of the Basel Convention, 2003). China and Brazil are among countries which have recently undergone transformations with regards to this sector (Liu et al., 2017; World Economic Forum 2020): important steps likely included imposing extended producer responsibility on battery manufacturers and mandating that recycling units are of a minimum (economical) capacity (Gottesfeld, 2017). However, there is still a need for evidence to identify the most effective interventions to facilitate this transition in LMICs, including of extended producer responsibility; responsible sourcing regulations; deposit schemes; and different enforcement approaches. The challenge is thus more difficult than for spices and paint, which have established "play books"—however, it is still amenable to broad-based best practices policies coupled with regulatory intervention and should be solvable at scale with experimentation and sufficient political will.

We also note the urgent need to address lead contamination of ceramic and aluminum foodware. Lead glazes are added to ceramics in order to control moisture and add shine, but when fired at an insufficient temperature, can leech into food. The manufacturing process also presents a severe risk to potters and their families. More recently, lead leeching has been identified in aluminum-based pots produced from scrap metal; high BLLs among resettled Afghan populations in the United States have been linked to the use of such cookware (Fellows et al., 2022). A recent study by Pure Earth (Pure Earth, 2023) found high prevalence of lead contamination in this type of cookware. The same study found that 70 percent of pots leached significant quantities of lead in an experiment which simulated the effect of cooking acidic food. This suggests that contaminated metal and ceramic foodware could be quite a significant source of population lead exposure, although more research is required to understand the conditions that make leeching occur and lead bioavailable. Unfortunately, the small-scale of manufacturing makes regulatory intervention in this space challenging. There is a pressing need for further research to help define the market structure for leaded cookware, and design, and evaluate effective interventions to prevent lead exposure through cookware, either by removing contaminated products from markets/households or by preventing leeching into food and drink.

35 The importance of local evidence in motivating government action was extensively discussed by the Working Group; though the total sample size of government engagement is still small, there were many notable examples where local evidence appeared to be highly influential. In India, NITI Aayog—the leading state think tank—was initially skeptical of international estimates of India's lead poisoning burden; credibility was substantially increased after a validation study by a local group (NEERI-CSIR) confirmed the findings (Kumar et al., 2022), and further boosted after similar findings from the Indian Council of Medical Research (Upadhyay et al., 2023). At a Delhi high-level roundtable in April 2023, co-hosted by several working group members, India's Secretary of Health and Family Welfare Mr. Rajesh Bhushan reported that the ICMR results were crucial in elevating his perception about the extent of the problem. In Georgia, concern was initially raised after the New York City Department of Health reported high levels of lead exposure in communities of Georgian ancestry and high lead levels in some Georgian spices (Hore et al., 2019); this kicked off a round of extensive local data collection, including blood lead testing within the 2018-2019 UNICEF Multiple Indicator Cluster Survey (see in Silverman Bonnifield and Todd, 2023, 25), which in turn prompted extensive government action for detection, clinical management, and enforcement. Likewise, LEEP begins its national engagements with a study analyzing the lead content of paints available on the local market. The results of the study (often showing high lead concentrations) offer compelling local evidence about the extent of the problem and a useful entry point for outreach to the relevant government ministries/regulatory bodies. Experience in Nigeria (SRADev, 2017) and the Philippines (Calonzo and Fontejon-Enarle 2019) also demonstrates the utility of local data and paint studies in motivating government engagement and/or regulatory action.

36 This is a rough, order-of-magnitude estimate, intended to provide general guidance on the scale of international investment required to mobilize scaled policy action in LMICs. It is based on the following components, with associated rationales (see table below). Our simplified costings assume that costs in all countries will be the same; in practice, however, costs are likely to vary substantially across countries, and interventions will need to be designed/tailored to local context. We caution that delivery of an intervention (e.g. spices or paint) is not guaranteed to result in the desired outcome (i.e. removal of contaminated products from market). We note that this estimate only covers *international* investments; the short- and long-term effectiveness of lead will also require complementary investments by the governments of affected countries. Finally, we note that this estimate only covers *policy advocacy, reform, research, and regulation*; it excludes site remediation and clean-up, which can be highly cost intensive.

COMPONENT	RATIONALE FOR COSTING	TOTAL (US$ M)
Country-Level Assessment, Technical Support, Capacity-Building	We do not have reliable country-level data on blood lead levels (BLLs) (outside of Georgia and Mexico). Existing estimates suggest that—excluding very small countries and conflict/fragile states—there are about 50 LMICs where lead poisoning remains widespread. We estimate that about $3 million in support through 2030 is needed per country to engage governments and industry; assess BLLs; conduct source analysis; build basic testing, surveillance, and detection capabilities, including for follow-up BLL testing and reporting; and provide technical support in drafting and enforcing regulations. Most of this support would be technical/programmatic, but there would be some scope for purchase/donation of surveillance and lab equipment. For example, purchase of 20 X-ray fluorescence devices for basic detection and enforcement capabilities would cost approximately $600,000 per country. A substantial portion of the programmatic support (for technical assistance and capacity-building) could be provided by secondments/in-kind technical support by partner governments.	150
Vertical: Paint	Excluding very small countries and conflict/fragile states, there are approximately 50 to 60 countries where current sales of lead paint are thought to be highly prevalent. These include countries that do not currently regulate lead in paint; countries with lax regulations; and countries yet to effectively enforce existing regulations. LEEP estimates that their end-to-end intervention to remove lead paint from the market costs up to $500,000 per country, depending on the size of the country and the extent of follow-up required. This includes an initial paint study; support for the development and enforcement of the paint regulation; manufacturer support to discontinue use of lead in paint; and follow-up studies over a number of years for monitoring and targeting further support (Lucia Coulter, personal communication).	25
Vertical: Spices	There are approximately 10 countries where contamination of spices is thought to be a major issue, spread across North Africa and South and Central Asia. A prior (successful) intervention to remove spices from market in Bangladesh was costed at $560,000, including a large cost component for source attribution (Jenna Forsyth, personal communication). We estimate that replicating the Bangladesh intervention in other affected countries will cost roughly $500,000 per country.	5

COMPONENT	RATIONALE FOR COSTING	TOTAL (US$ M)
International Coordination, Reporting, and Standard Setting	We estimate that approximately $2 million per year—$14 million over seven years—is needed to support the WHO and UNICEF in fulfilling their desired roles in international coordination, reporting, and standard-setting.	14
Research, Development, and Standard-Setting: Testing and Detection Methods	Further work is needed to develop and validate more appropriate testing and practical detection methods for use at-scale in LMICs. On the testing side, the existing point-of-care platform (Lead Care II) is cost-prohibitive to most LMICs (about $10 per test) and unable to detect BLLs below 3.5 µg/dl. Alternative tools that would be desirable from a LMIC perspective include less expensive point-of-care testing (POCT), potentially to include competitive POCT platforms; or rapid triage tests indicating whether an individual is above or below certain BLL thresholds (e.g., above or below 45 µg/dl, where chelation therapy might be indicated; or above or below 5/10 µg/dl, where families might receive information about lead exposure prevention). On the practical detection side, x-ray florescence (XRF) devices are highly effective, but they are costly (roughly $30,000 each) and work is still needed to standardize calibration settings and methods to produce replicable, scientifically valid, and comparable readings/results. Advances here could include better standard setting for existing XRF technology; development of more affordable/robust XRF devices for use in LMIC field settings; and/or development and validation of other low-cost practical detection technologies for use by families and local health workers in the home and other environments of potential exposure.	20
Research and Evaluation: Global	While increased country-level BLL evaluation and source analysis will help fill some knowledge gaps about the extent of the problem, there are additional research needs at the global level that represent global public goods, helping mobilize and inform effective action across all countries. These include research to identify priority sources of exposure (especially among pregnant/reproductive age women and children) across focal countries; development and evaluation of better/less expensive remediation techniques; market and scientific interventions to reduce lead exposure, e.g., via battery recycling or cookware; global estimates about the burden; and continued investigation into the harms and impact of lead exposure in LMICs.	60
Advocacy	A steady drumbeat of advocacy at the international, national, and sub-national levels is needed to build momentum for action; increase pressure on governments to effectively regulate lead; and hold governments, industry, and international organizations accountable for taking effective action.	76
Total		**350**

37 “Closer to zero” is a nod to a US Food and Drug Administration (FDA) initiative that aims to minimize dietary exposure to lead and other contaminants, with priority given to foods primarily eaten by babies and young children (see FDA n.d.). In terms of blood lead levels (BLLs), we recognize that it will not be possible to entirely eliminate lead exposures, given the extent to which lead has already been displaced from the earth's crust and deposited into the surface environment. However, in the medium-term, it should be possible for most or all countries to achieve current BLLs found in wealthier countries, e.g. the United States where average BLL in children was 0.6 µg/dL as of 2018 (Egan et al., 2021). In the long-run, countries should aspire to suppress lead levels even further; this can either be considered “closer to zero” or “toward pre-industrial levels,” which have been estimated at 0.016 µg/dL (Flegel and Smith, 1992). Note that this estimate implies that even US BLLs, which are relatively low, still exceed human evolutionary conditions by a factor of 38.

38 The WHO's Guideline for Clinical Management of Exposure to Lead, released in 2021, provides evidence-based recommendations on the diagnosis of lead poisoning, as well as the use of gastrointestinal decontamination, calcium supplementation, and chelating agents for treatment. Specific recommendations vary by patient populations; calcium supplementation and preventative interventions are generally recommended at BLLs above 5 µg/dL, and chelation therapy at BLLs above 45 µg/dL. Chelating agents recommended in the guidelines include succimer, penicillamine, sodium calcium edetate, and dimercaprol; of these, penicillamine is included on the core WHO Model List of Essential Medicines (2023). The other three chelating agents are included on the “Complementary List,” which “presents essential medicines for priority diseases, for which specialized diagnostic or monitoring facilities, and/or specialist medical care, and/or specialist training are needed. In case of doubt medicines may also be listed as complementary on the basis of consistent higher costs or less attractive cost-effectiveness in a variety of settings.” Specific aspects of the guidelines may need to be modified during adaptation to some LMIC settings, e.g. individualized preventative intervention for BLLs above 5 µg/dL is unlikely to be feasible in the short-term in settings where average BLLs exceed this threshold.

Working Group Members

The above statement does not necessarily represent the views of all Working Group participants (or the groups with which they are affiliated); nor does it represent a policy commitment from any individual or institution. Some members of the Working Group (listed above) have opted to sign the statement in their individual capacities. Otherwise, members of the Working Group (listed below) served in their individual capacities and have provided input that informed the final statement, but they do not necessarily endorse its contents.

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